Safe paediatric intensive care

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Abstract: In order to optimise safety within the paediatric intensive care unit (PICU), it is essential to optimise organisation, identify problem areas and implement standards and guidelines for safe practice (with appropriate monitoring). Organisational issues have a major impact on safety: the introduction and—recently—centralisation of paediatric intensive care, the appointment of dedicated paediatric intensivists, nursing staffing, handovers, rounds, the number of work hours and night shifts with the associated problems of disturbed circadian rhythms. The technique of voluntary, anonymous, non-punitive critical incident reporting has the potential to identify incidents and latent errors before they become self-evident through a major incident. This systems approach focuses on organisational and communication problems. Standards and guidelines may help in weighing up the benefits and risks of invasive procedures, and interventional studies have shown that implementation of standards and guidelines can improve outcome. Mortality prediction models enable us to monitor quality of care and, thus, to investigate the best ways of organising intensive care and monitoring the effects of changes in practice

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REVIEW

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Part 2: Workplace organisation, critical incident monitoring and guidelines

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Abstract In order to optimise safety within the paediatric intensive care unit (PICU), it is essential to optimise organisation, identify problem areas and implement standards and guidelines for safe practice (with appropriate monitoring). Organisational issues have a major impact on safety: the introduction and—recently—centralisation of paediatric intensive care, the appointment of dedicated paediatric intensivists, nursing staffing, handovers, rounds, the number of work hours and night shifts with the associated problems of disturbed circadian rhythms.

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Keywords Paediatrics · Safety · Critical incidents · Organisation

Introduction

In order to optimise safety within the paediatric intensive care unit (PICU), it is essential to optimise organisation, identify problem areas and implement standards and guidelines for safe practice (with appropriate monitoring).

Workplace organisation

There is little doubt that paediatric intensive care has improved paediatric outcome. For Victoria, Australia, it was estimated that the mortality rate for children under 15 years of age would double from 7.1 to 14.6 deaths per 1000 live births without paediatric intensive care [1].

Several organisational changes in the care of seriously ill neonates and children have improved outcome. Most importantly, this applies to the introduction of separate PICUs. The first separate PICUs in Europe were established in Sweden in the 1950s [2]. Over the following decades a new discipline evolved from traditional paediatrics, with a different approach to patient management, focusing on stabilisation of vital parameters before the establishment of a diagnosis. Furthermore, the paediatric intensivist became a specialised generalist in a discipline not organised along traditional organ system models but, instead, comprising neonates and children with the common attribute of life-threatening illness.

With the development of severity of illness scores [3, 4, 5, 6, 7] it has been possible to establish that the centralisation of paediatric intensive care [8] and the appointment of dedicated paediatric intensivists [9, 10] are associated with significant improvements in patient outcome and cost of care. Centralisation of paediatric in-

tensive care may nearly halve the risk-adjusted mortality for children requiring intensive care [8]. The exclusive presence of residents, particularly junior residents, in the PICU may adversely affect patient outcome, while the appointment of paediatric critical care fellows in addition to residents may significantly improve outcome [11].

The benefits of centralisation have also been shown for paediatric heart surgery. For children with a congenital heart defect who underwent surgery in California in 1988 or Massachusetts in 1989, the risk of dying in-hospital was much lower if the surgery was performed at an institution performing more than 300 cases annually [12]. A further argument for regionalisation is given by Tilford et al. [13], who showed that the volume of patients in PICUs is inversely related to risk-adjusted mortality and patient length of stay.

There are also significant questions about the appropriate levels of nursing staffing. While there is a general belief that risk adjusted mortality is higher in hospitals with high patient-to-nurse ratios [14, 15], a retrospective study from an Australian neonatal ICU suggests the opposite: infants exposed to higher infant to staff ratios had an improved adjusted risk of survival [16]. This provocative result was partly explained by the increased handling of small, unstable infants that may occur when more nursing staff are available to perform care. There is also suspicion that technology actually does not release staff, but pushes up costs of staff by requiring more highly specialised nurses to operate the equipment on the patient. In countries with limited resources, the situation is quite different: increased numbers of well-trained nurses significantly reduce in-hospital neonatal mortality [17].

A problem specific to intensive care is the need for 24-h continuity of care, with the associated issues of shift work with handover (as interruptions in the continuity of patient care) and the requirement of balancing patient needs for normal circadian rhythm against the need for night staff to adapt normal circadian rhythms. There is no doubt that fatigue impairs performance [18], and it is essential that work hours are not excessive. Shifts, however, create problems for staff (family communication as well as sleep and distorted diurnal rhythm) and a balance has to be achieved between reasonable working shifts (so that fatigue does not become a factor in individual performance) and continuity of care for individual patients. Shifts can be timed to facilitate family communication for staff, but this may be complicated by the fact that, in many parts of the world, it is difficult for staff to travel safely to and from work after dark.

In order to enhance normal circadian rhythms of the patients, most ICUs use only dim light during nights. This work environment may impede the cognitive function of staff and may give rise to errors. Achievement of a phase delay of the circadian rhythm [19] is enhanced by exposure to bright artificial light (at least 2500 lux) during night shift, especially at its end, and darkness for daytime sleeping and prolonged periods on the night shift. It has been shown that humans exposed to very bright light during night shift had completely adapted their circadian rhythm after 4 days and had greatly improved alertness and cognitive function compared to controls [20].

Failures of communication, particularly those that result from inadequate handovers between clinicians, remain among the most common factors contributing to the occurrence of adverse events [21]. Handovers have to be formalised, with a balance between the time required for, and the adequacy of, the communication. Like pilots who go through a checklist before each take-off, ICU staff should go through checklists at each handover and probably at regular intervals in between. In one study 50% of critical incidents were detected by routine checks [22].

Another delicate phase of an intensivist's day regarding patient safety is the round. Organisational measures should allow for undisturbed rounds. The intensivist should concentrate on patient inspection.

Data from the airline industry have shown that hierarchical structures are not good for safety. This may also apply to ICUs. A further significant risk factor for poor performance is conflict in workplaces. There should be structures in place to ensure that conflicts are identified and resolved, such as daily "reflection" circles with nursing and medical staff participating.

The physical, emotional and mental well being of paediatric intensivists is an important safety factor. One study from the USA showed very high levels of burnout among paediatric intensivists (36% being at risk for burnout, 14% being burned out) [23]. Intensely personal and, at times, disturbing feelings (the "dark side" of pae-diatric intensive care) are normal and expected in the PICU environment. The recognition and management of these feelings during fellowship years are an essential part of developing a professional identity [24], and also for the optimisation of patient care and safety.

Critical incident monitoring

In order to optimise safety within the PICU, it is essential to monitor the occurrence of both complications [25, 26] and critical incidents. Whereas a complication is an unexpected, adverse condition harming the patient, a critical incident is any event which could have, or did, reduce the safety margin for the patient [27]. The spectrum of critical incidents is wider than that of complications. As a critical incident may not have had adverse results for a patient, it is often much easier to focus on the problem and identify solutions than it is if patients have suffered as a result of the event. Therefore, for quality improvement purposes, monitoring of critical incidents may be superior to monitoring of complications. The prerequisite to reporting is a fundamental change in hospital culture, away from the traditional mode of apportioning blame to incident pre-

cipitators. In aviation, this principle was recognised a long time ago and confidential reporting systems to deal with it are well-established [28].

In order to make as many critical incidents as possible known to the intensive care team, the technique of voluntary, anonymous, non-punitive critical incident reporting was implemented, first in anaesthesia and adult intensive care [27, 29, 30, 31, 32,]. In paediatric intensive care, the first reports on anonymous incident reporting dealt with medication errors [33, 34]. A recent study examined overall critical incident monitoring in neonatal and paediatric intensive care [22]. All these studies show alarmingly high figures and at present there is increasing awareness of the occurrence of human errors, both in the medical community and in society [35].

Incident monitoring alone does not necessarily improve the quality of care. It is essential to identify the context in which that incident took place and then to identify appropriate solutions. A further important step in quality control was the introduction of the system approach [28], which regards errors and deviations not as human failures, but as opportunities to improve the system. Humans err and will continue to do so [22, 27, 32]. We have to design around that fact, with sufficient filters to prevent those errors affecting patient outcome. The system approach focuses on organisational and communication problems. A component of the monitoring which gives us important clues for system changes is the context in which things happen: staff training, staff seniority, supervision situation, workload at the time (including the factors that actually add to workload and stress). The whole intensive care team must be actively involved in the analysis of critical incidents through regular discussion [22].

Interventions to prevent the recurrence of critical incidents may extend well beyond the PICU and even the hospital. It was possible to reduce the potential confusion of different drugs in almost identical packaging after changing the colour of the packaging of one of these drugs. This system change was made possible through cooperation between health care providers, the national drug control agency and the manufacturer [36]. Further, critical incident monitoring was able to identify the repeated occurrence of adverse events of unknown aetiology, thus facilitating their clarification and preventing their recurrence [37].

Voluntary critical incident monitoring does not allow tracking the quality of care [36, 38], that is, the number of reported incidents does not correlate with the true number of incidents and definitely not with mortality. Therefore, models that predict the risk of mortality in children in intensive care are needed to allow evaluation of the quality (effectiveness and efficiency) of paediatric intensive care [3]. Mortality prediction models enable us to: investigate the best ways of organising intensive care (by comparing different units); monitor the effects of changes in practice (by observing trends within units over time); assess the relationship between severity-of-illness and length-of-stay or cost and monitor the effects of rationing intensive care [4]. Thus, mortality prediction models may be an important tool in our efforts to reduce the risks of intensive care. The currently used paediatric severity-of-illness scores are the Pediatric Risk of Mortality (PRISM) score, updated in 1996 (PRISM III) [5] and the Paediatric Index of Mortality (PIM), updated in 2003 (PIM2) [6]. PRISM III is calculated from 72 worst-in-24-h variables. PIM2 is based on data at admission and it needs ten variables for risk calculations. PRISM and PIM do not correctly predict the mortality of infants less than 1 month of age. An established scoring for newborns is the Clinical Risk Index for Babies (CRIB), updated in 2003 (CRIB II) [7].

When mortality prediction models are used, accurate data collection is critically important. Sufficient resources must be available so that all the information is collected and checked by a small number of enthusiastic and careful people who are properly trained [6]. A problem remains the collection of data for children who should have had intensive care, but never made it to the unit.

Standards and guidelines

In the multidisciplinary field of intensive care, the intensivist, as the primary treating person, has an important role in weighing up the benefits and risks of available invasive diagnostic and therapeutic procedures. The establishment of standards and guidelines may assist in this process. Standards refer mainly to the structure of the intensive care unit (personnel, equipment) and are used as quality control instruments. They define the goals which have to be achieved. Guidelines refer to the processes of care. Guidelines define the limits within which decisions can be made on specific clinical problems.

System redesign with new standards can be a big step forward in patient safety, as illustrated by the use of different connecting fittings for oxygen and nitrous oxide. This change makes it virtually impossible for a patient to die because of a wrongly connected oxygen line [39]. There is huge scope for application of these principles in other areas of the ICU. In newborn babies with respiratory distress syndrome, surfactant given via the endotracheal tube is an established therapy. This is usually done using pumps and tubing designed for intravenous infusions, with the result that inadvertent venous infusion of surfactant is possible with serious consequences for the baby [40]. As with oxygen and nitrous oxide, it should be impossible to connect an intravenous line to the endotracheal tube. The same applies to the confusion of nasogastric and parenteral feeding lines [41] as well as intravenous and intrathecal access [39]. Currently, accesses to venous, arterial, cerebrospinal fluid, tracheal, enteral and urinary systems often share the same fittings, making

catastrophic confusions possible. A task group from the European Standards Organisation (CEN) recommended that different connections should be used in lines and syringes for vascular, enteral, respiratory and neuraxial access [42]. It is also possible to connect ventilator circuits incorrectly, for example in such a way that the humidifier temperature probe is on the expiratory rather than the inspiratory limb with resultant overheating of gases to the patient.

Guidelines may be a means of reducing physician practice variability. In adult general hospitals, individual physician practice was a significant determinant for length of stay in patients within a specific diagnosis-related group and with the same severity-of-illness scores [43]. To do so, they should be evidence-based as well as taking local experience and circumstances into account. In many cases, however, the evidence is lacking. Even so, standards and guidelines make sense by enabling a "unité de doctrine" which helps to facilitate and simplify the daily running of the ICU.

Interventional studies have shown that new standards and guidelines can reduce error rates and improve outcome [44, 45, 46, 47]. Interestingly, most improvement is reached during the initial phase of the introduction of the new guideline (observational effect) with subsequent stabilisation at a slightly worse level, which is still better than prior to the intervention. There are also some studies documenting the successful introduction of new guidelines in neonatal and paediatric intensive care. The rate of central line infections in neonatal intensive care decreased after the introduction of new guidelines for central line care [44]. The rate of infection with coagulase-negative staphylococcus and the rate of supplemental oxygen at 36 weeks adjusted gestational age decreased after implementation of "potentially better practices", developed through analysis of the processes of care, literature review and site visits [45]. Methicillin-resistant *Staphylococcus aureus* (MRSA) infection rate decreased after the implementation of infection control measures directed towards limiting person-to-person spread in a PICU [46]. Intubation time and length of stay decreased after standardisation of pain management in an ICU [47].

There are still multiple areas in neonatal and paediatric intensive care lacking evidence-based guidelines. One such clinical problem is the indication for blood transfusion in anaemia of prematurity. This example, however, reflects some of the difficulties associated with the development of guidelines. Transfusing blood is an invasive procedure, carrying a significant risk. Haematocrit is a relatively poor indicator of the adequacy of the provision of oxygen to the tissues [48]. Blood lactate, which is increased in anaerobic metabolism, might be a more accurate indicator of clinically significant anaemia, but has the problems of considerable variability in stable premature infants, lack of correlation with other possible indicators of compromised oxygen delivery and probable multifactorial pathophysiology of hyperlactacidaemia [49]. There is still no single, reliable and easily obtainable indicator of the adequacy of systemic oxygen transport in anaemia of prematurity and the indication for transfusion is mainly based on the subjective, clinical impression of the attending physician. This is reflected in major differences in transfusion practices for very low birth weight infants between different neonatal ICUs [50, 51].

Guidelines need to be adapted to local circumstances. One example is the usefulness of the left shift of neutrophils as an indicator of sepsis after paediatric cardiopulmonary bypass (CPB) [52]. CPB causes systemic inflammatory response syndrome (SIRS) with activation of neutrophils [53]. Neutrophil activation is reflected in the peripheral blood as a rise of the absolute neutrophil count and a left shift of neutrophils (increased immature-to-total neutrophil ratio, IT ratio). By plotting the 95% confidence limits of the IT ratio of controls against postoperative day and comparing these limits with the IT ratio courses of children who developed sepsis after CPB, it has been shown that the IT ratio remains a sensitive indicator of sepsis even after CPB [52]. The graph of the 95% confidence limits can thus be used in evaluating children with suspected sepsis after CPB. However, this guideline is restricted to the hospital where it was developed, because the local technique of CPB may influence the magnitude of the SIRS and the morphological definition of segmented neutrophils and band forms differs between laboratories.

Research

During the last few decades, neonatal and paediatric intensive care has made major advances through the introduction of new technologies. The drawbacks and risks of too enthusiastically applied invasive procedures and of the increasing complexity have been less appreciated so far. The focus of current research remains the development of new technologies and treatments. In contrast, relatively little effort has been targeted at the perfection of operational systems which are partly responsible for the well-documented problems with medical safety [54]. Fu-ture research has to be devoted to safety issues too: evaluating current clinical practices and identifying their limitations. We need data on the benefits and harm of treatments, enabling the development of evidence-based guidelines. System changes have to be monitored and evaluated by objective outcome measures, such as mortality prediction models. Medical technology research has to focus on the development of non-invasive, reliable diagnostic and therapeutic tools, thus replacing risky invasive procedures. Finally, an effort has to be made to bring about a cultural change in the medical profession, so that findings suggesting harm are no longer discounted.

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